Merritt TSA inventory audit

Introduction

The Ministry of Forests conducts an inventory of each timber supply area (TSA) in British Columbia every 10 to 30 years—using standards and procedures developed by the Resources Inventory Program. Regular updates are undertaken to reflect changes in the timber volume due to growth and to depletions from harvesting and natural causes.

This report presents the results of an inventory audit performed within the Merritt TSA. The Merritt TSA is in the Kamloops Forest Region and is administered from the Forest District office in Merritt. Located between the Cascade Mountains to the west and the Thompson Plateau to the east, the area encompasses two main drainage systems, the Tulameen-Similkameen in the south, and the Coldwater-Nicola in the north. The TSA comprises approximately 1.12 million hectares.

Purpose of the audit and application of the results

It is often asked, "How accurate is the current inventory?" To answer this important question, the Ministry of Forests has developed an inventory audit methodology specifically designed to test the overall accuracy of estimates of the total standing volume in each timber supply area.

This inventory audit methodology entails sampling three primary components of the inventory: mature forests, immature forests, and non-forest areas.

The objective of the inventory audit program is to help identify TFLs or TSAs where the forest inventory needs attention. Enough samples are taken to ensure statistically reliable results for the TSA as a whole.

The amount of data collected, however, is not sufficient to make statistically reliable conclusions about specific areas or tree species. For example, any overall differences highlighted by the audit could result from problems with one tree species, from part of the land base (such as high elevation rather than lower elevation areas), from one age group of forest stands, or from a combination of these and other factors. As a consequence, general audit results cannot appropriately be used to adjust information about the forests currently available for timber harvesting since this area constitutes only a portion of the total forested area in the TSA.

The audits provide information that may be useful to the Chief Forester when determining the allowable annual cut—offering a general assessment of the uncertainty associated with mature timber volumes, immature site index, and the non-forest classification. However, the audit results cannot justifiably be used to make specific adjustments to growth and yield and other information used in timber supply analyses and allowable annual cut determinations.

Methods

Current inventory

There are 37 TSAs in British Columbia, varying in size from approximately 70 000 hectares to 13 million hectares. Inventories of each TSA are conducted through a multistage process. Polygons are first delineated from 1:15 000-scale aerial photographs. Photo-interpretation is then used to produce data on a number of attributes for each polygon. These attributes include species composition, stand height, age, and crown closure. Timber volume is then estimated indirectly using the photo-interpreted variables and an empirical yield model.

To keep estimates current, inventories are regularly updated to account for forest growth and for depletions due to harvesting, fire, and the impact of insects and disease damage. Empirical yield models, such as the Ministry of Forests Variable Density Yield Prediction (VDYP) computer model, are used to update the inventory for forest growth. Field visitation, satellite imagery, and aerial photographs may be used to update the inventory for depletions.

Inventory audit procedures

The inventory audit tests three components of the current inventory. The first component is the mature forested areas (forest stands older than 60 years). The inventory audit tests the accuracy of the mature timber volume. The second component tested is immature stands (younger than 60 years but older than the silvicultural classification of free

growing). The audit tests the accuracy of the site growth potential (site index) assignment for these stands. The third component tested is the area classified as non-forest in the inventory, which includes areas such as lakes, gravel pits, and alpine meadows. The audit tests the accuracy of the photo-interpreted classification for this component.

Mature component assessment criteria

To test the mature component of the inventory, the existing inventory's estimate of the mean mature volume per hectare for the TSA (*the inventory volume*), is compared with a new estimate of the mean mature volume per hectare obtained from the audit samples (*the audit volume*).

The difference between these two estimates is called the total bias. A test is conducted on this bias to determine if it is statistically significant. This test establishes whether there are detectable differences between the audit volume estimate and the inventory volume estimate, for the total forested area of the TSA.

If the total bias is found to be statistically significant, further analyses are conducted to determine if the specific source of bias within the inventory is one of the following:

- *classification bias:* This is caused by incorrectly estimating the polygon attributes; or
- *model bias:* This is caused by poor prediction from the yield model, which was developed for large areas of the province and was not designed for specific management units.

The analysis to determine the source of bias uses an estimate of the mean mature volume per hectare for the TSA called the *ground attribute volume*. This is calculated from audit sample attributes (stock and stand table estimates of species composition and stocking, and ground-based averages of top height and age), along with crown closure taken from the original map label, using the yield prediction model. The difference between the ground attribute volume estimate and the audit volume estimate approximates the bias associated with the yield model. The difference between the audit volume estimate and the inventory volume estimate not accounted for by the model bias approximates the bias associated with the inventory classification attributes. Once the source is identified, further analyses may be done on the inventory classification attributes or the yield model itself.

Immature component assessment criteria

Accuracy of the inventory classification for immature stands is tested by examining the site index assignment. Since the immature forest stand site index provides an estimate of site productivity, its accuracy affects the projection of long-term harvest levels.

Data gathered is examined to determine how closely the audit and inventory site indices match for individual samples, and to explore potential trends.

Non-forest component assessment criteria

The audit test for the non-forest component of the inventory assesses the accuracy of the non-forest classification assignment. An airphoto interpreter certified by the Ministry of Forests compares the non-forest inventory classification to a suitably-scaled forest cover aerial photograph. Classification accuracy is rated using a point scoring scheme to determine an overall accuracy percentage. The acceptance criteria for this test is 85% or higher.

Merritt TSA audit sampling procedures

The **Merritt** TSA sample used updated maps based on an inventory originally conducted between **1991 and 1995**. A list of all polygons identified on these maps was produced and sorted on a number of stand characteristics (site quality, age, and species group). Polygons were systematically selected from this list by a process designed to produce a representative sample of the TSA.

For the mature forested component of the inventory audit, a random sample of 50 forested polygons from the total forested area in the TSA was selected for sampling.

Up to 4 full-measure prism plots and 5 count plots were established within each of the 50 sample polygons. The plots were located systematically, using a square grid and a random start point. The grid interval varied with polygon size. To reduce sample costs for large or irregular polygons, only a randomly selected portion of the polygon was sampled. A total of about 200 full-measure and 250 count plots were established. Field data collection and compilation followed Ministry of Forests cruising and cruise compilation procedures. The objective was to obtain audit volumes that were comparable (in terms of utilization standards and merchantability definitions) to the inventory volumes produced from the VDYP computer yield model.

The VDYP system produces net merchantable volume per hectare defined as stem volume inside bark of all live trees excluding a 10 cm diameter inside-bark top, a 30 cm high stump, and decay (as estimated from Ministry loss factors). Dead potential and veteran trees are not included in the VDYP estimates. This volume is calculated for a

utilization standard defined as all live trees of 12.5+ cm dbh. When considering the audit results, it should be noted that there are some differences between the utilization standards applied in the audit and those used operationally.

The audit volume estimates were then compared to the inventory volume estimates (from VDYP) to test the validity of the current inventory. A paired comparison *t*-test was used to test for significant differences. The precision of the inventory volume estimates—how well each inventory volume estimate corresponds to the audit volume estimate on a sample-by-sample basis—was assessed by measuring the statistical correlation. The data was then post-stratified to detect trends related to the operable and inoperable forested land base distribution of the sampled polygons.

From the immature forested component, a random sample of 20 polygons was selected for sampling. Up to 9 inventory ground calls were established within each of the 20 sample polygons. The plots were located systematically, using a square grid and a random start point, similar to the mature volume component. A total of about 180 ground calls were established and data collection followed the standard Ministry of Forests inventory ground call procedures.

To audit the non-forest component, a random sample of 30 non-forest polygons was selected. Standard Ministry of Forests inventory airphoto classification techniques were used to compare the 30 non-forest polygon classification assignments to corresponding airphoto checks.

Inventory audit results

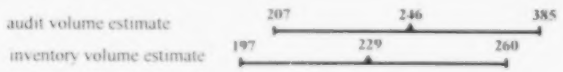
Analysis of mature volumes

Results of the inventory audit for mature volume at the 12.5+ cm dbh utilization limit for the total forested area are given in Table 1.

Table 1: Statistics for the audit volume and inventory volume estimates at 12.5+ cm dbh utilization (net decay), Merritt TSA

	Audit Volume Estimates	Inventory Volume Estimates
Number of Samples	50	50
Mean (m^3/ha)	246	229
Coefficient of variation (%)	55	49
Standard error	19.3	15.8
Sampling error (%)	15.8	13.9
95 % confidence interval (m^3/ha)	207 - 385	197 – 260
Correlation coefficient	R = 0.679	
Ratio of means (audit/inventory vol.)	= 1.08	

Bar graph representation of 95% confidence intervals (in m^3/ha)



The correlation coefficient of 0.679 for the audit and inventory estimates indicates a strong relationship among the individual samples. There is a 17 m^3/ha difference between the mean inventory estimate for mature volume (229 m^3/ha) and the audit estimate (246 m^3/ha). A paired-sample *t*-test determined that, for the mature component of the total forested area of the TSA, this difference is not statistically significant 19 times out of 20. The 95% confidence interval for the mean paired difference is -12 to +46 m^3/ha.

Since there is no statistical difference between the two estimates, the ground attribute volume was not calculated.

Analysis of operable and inoperable volumes

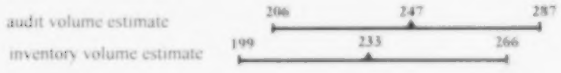
To provide audit results more likely to be applicable to the timber supply planning process, an approximation was made of the forested areas considered currently available for timber harvesting (operable areas). The audit results were post-stratified based on this approximation. Results of the inventory audit for samples in the operable forested areas in the TSA are given in Table 2.

Table 2: Statistics for the audit volume and inventory volume estimates at 12.5+ cm dbh utilization (net decay), operable areas, Merritt TSA

	Audit Volume Estimates	Inventory Volume Estimates
Number of Samples	45	50
Mean (m^3/ha)	247	233
Coefficient of variation (%)	55	48
Standard error	20.1	16.5
Sampling error (%)	16.4	14.3
95 % confidence interval (m^3/ha)	206 - 287	199 – 266

Correlation coefficient	R = 0.644
Ratio of means (audit/inventory vol.)	= 1.06

Bar graph representation of 95% confidence intervals (in m^3/ha)



For the 45 samples located within the operable forested area, the mean audit volume is 247 m^3/ha and mean inventory volume is 233 m^3/ha. The difference between these two estimates (14 m^3/ha) is not statistically significant, 19 times out of 20.

Five samples were in inoperable forested areas. This sample size is too small to allow any meaningful comparisons to be made. Because of the high variability and restrictive nature of conclusions associated with this small sample size, volume estimates from inoperable forested areas are not shown.

Analysis of immature inventory classification

Out of 20 stands sampled in the field, two stands were considered too young for an accurate site index assessment. Of the remaining 18 stands, the inventory correctly identified site index within ±3 m of the audit site index for 10 stands; the inventory site index was more than 3 m lower than the audit site index for 8 stands.

Analysis of non-forest inventory classification

Thirty stands classified as non-forest were assessed for accuracy of the inventory. The resulting score was 99%, which meets the provincial minimum standard of 85%.

The Discussion and conclusions

objective of the inventory audit in the Merritt TSA was to assess the overall accuracy of the current (1991 to 1995) Ministry of Forests inventory. The mature, immature, and non-forest components were tested.

Audit results for the mature component of the inventory suggest that the inventory is statistically acceptable. Subsequent analysis of post-stratified data also shows a similar level of acceptability in the operable forested area.

Audit results for the immature component suggest that the immature site index assignment may not be accurate. Further review of this component of the inventory is required.

The audit assessment of the non-forest classification in this TSA found it to be within provincial standards.

Glossary

accuracy: A measure of how close an estimate is to the true value.

allowable annual cut: The rate of timber harvesting specified for an area of land.

analysis unit: The basic building blocks around which inventory data and other information are organized for use in forest planning models, typically involving specific tree species or type groups that are further defined by site class, geographic location or similarity of management regimes.

bias: The quality of a measurement device or procedures that tends to result in a systematic misrepresentation of what is being measured.

coefficient of variation: A relative measure of variation within a population, calculated as the ratio between the standard deviation and the mean value.

confidence interval: The range of values within which the population parameter is expected to lie.

confidence level: The estimated probability that a population parameter lies within a given confidence interval.

correlation coefficient: A measure of the relationship between two variables. A value of 0 for the correlation coefficient indicates a random relationship, whereas a value of ±1 indicates a perfect positive or negative linear correspondence.

dead potential trees: Standing or down dead timber which is estimated to contain at least 50% of its original gross volume in sound wood.

diameter at breast height (dbh): The stem diameter (outside-bark) of a tree measured at breast height (1.3 metres above the point of germination) to the nearest millimetre.

field visitations: Ground-level field procedures designed to provide physical verification of polygon inventory attributes.

free-growing (crop): A crop of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs, or other trees.

inoperable lands: Lands that are unsuited for timber production now and in the foreseeable future because of their topography, inaccessible location, low value of timber stands, or designation for uses incompatible with timber production.

mean: The average value of a set of observations.

polygon: A portion of land area, delineated on mid-scale aerial photographs, of "like" or uniform land cover type.

pre-inventory assessments: Inventory activities to evaluate the existing forest inventory as a basis for deciding whether to re-inventory or update the current inventory, and to document the existing inventory, maps, and photos to support the execution of the reinventory or update if required.

public sustained yield units (PSYU): A portion of a TSA; an area of Crown land, usually a natural topographic unit determined by drainage areas, managed for sustained yield by the Crown through the Ministry of Forests. It includes all Crown lands within the currently established boundaries of the unit and excludes federal lands, provincial parks, experimental forest reserves, gazetted watersheds and tree farm licences.

ratio estimate: The ratio between two different estimates.

representative: The quality of a sample having the same characteristics as the population from which it is selected.

sampling: The process of selecting observations.

sampling error: The error attributed to sampling procedures.

significant difference: The results of a statistical test comparing either two or more estimates, or an estimate to a fixed value. If the difference is too large to be attributed to chance, the difference is said to be statistically significant.

site index: An expression of the forest site quality of a stand, at a specified age, based either on the site height, or on the top height, which is a more objective measure.

standard error: An expression of the absolute variability of an estimate.

standard deviation: A measure of the variation of the population.

timber supply analysis: An assessment of future timber supplies over long planning horizons (more than 200 years) by using timber supply models for different scenarios identified in the planning process.

timber supply area (TSA): An area defined by an established pattern of wood flow from management units to the primary timber-using industries.

tree farm licence (TFL): Privately managed Sustained Yield Units; designed to enable owners of Crown-granted forest lands and old temporary tenures or the timber licences which replace them, to combine these with enough unencumbered Crown land to form self-contained sustained yield management units.

variable density yield prediction (VDYP) model: An empirical yield-prediction system for natural stands based on data collected in temporary inventory sample plots (TSPs) and natural, permanent growth sample plots (PSPs). VDYP predicts volume (net decay) and diameters at four utilization levels using stand height, age, and density. The aerial approach uses crown closure as the density measure.

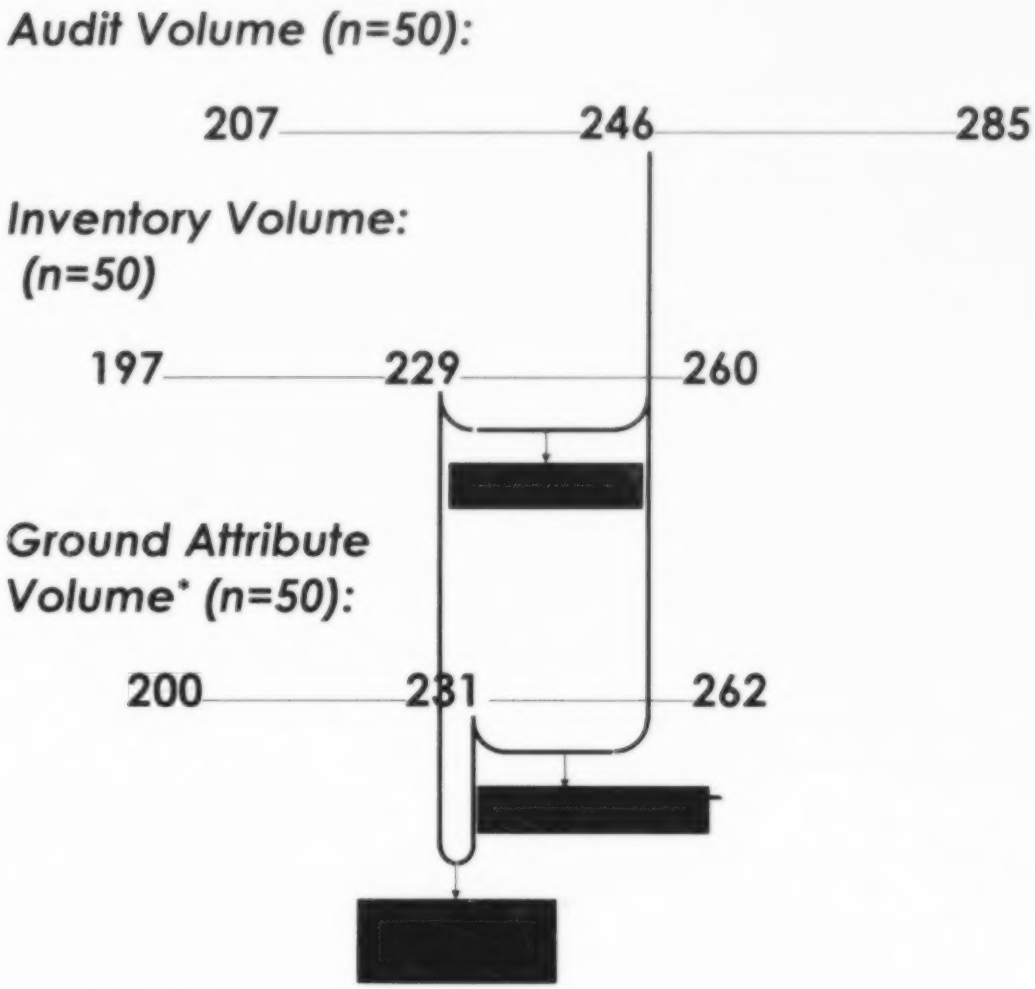
veteran trees: Mature living trees which are remnants of an older stand.

For more information

For more information or to obtain other inventory audit reports, contact: Director, Resources Inventory Branch, 722 Johnson Street, Victoria, B.C., Canada V8W 3E7, Phone 250-387-1314, fax 250-387-5999, or visit our web site at http://www.for.gov.bc.ca/resinv/

March 1998

Inventory Audit Results :
Overview Merritt TSA
May, 1997



* "Ground attribute" volume is calculated from audit sample attributes (i.e. "ground" attributes: stock and stand table estimates of species composition and stocking, and ground-based averages of top height and age), along with crown closure taken from the original map label, using the VDYP yield prediction model. The difference between the ground attribute volume estimate and the audit volume estimate *approximates* the bias associated with the yield model. The difference between the ground attribute volume estimate and the inventory volume estimate *approximates* the bias associated with the inventory classification attributes. These two bias components comprise the *total bias* in the inventory.

Audit Volume (Kozak) vs. Inventory Volume (Predicted in VDYP) (n=50)

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 12.5 cm + net merch. less decay only/Tree Class 1,2)*

207 ——— **246** ——— **285** Audit Volume
(15.8% sampling error)

197 ——— **229** ——— **260** Inventory Volume
(map label attributes predicted in VDYP)
(13.9% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$$R = \frac{\text{average audit volume}}{\text{average inventory volume}} = 1.08$$

1.0
↓

0.95 ——— **1.08** ——— **1.20**

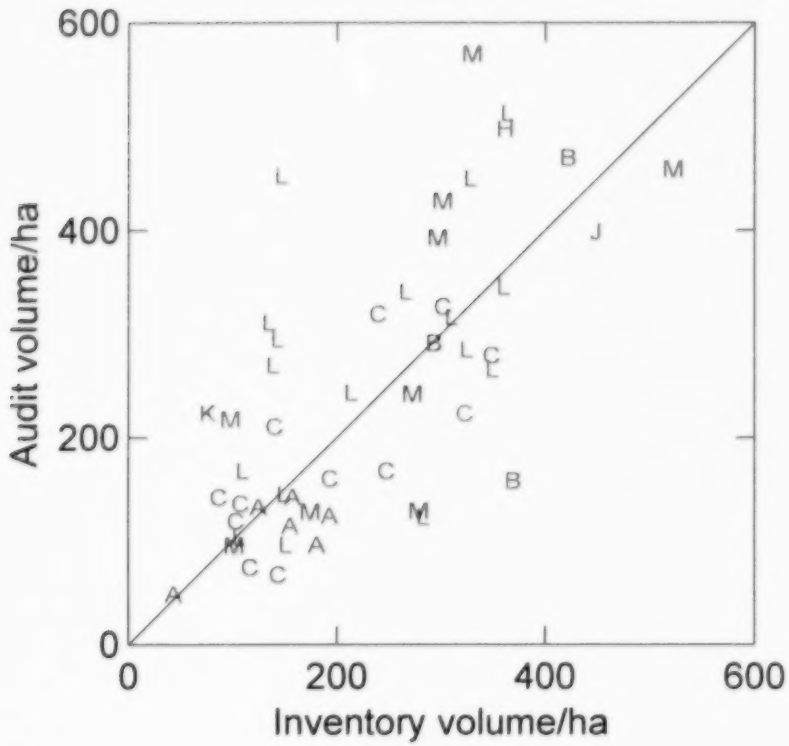
* *Since 1.0 is within the interval, the ratio indicates that there is no significant difference between the audit volume and the inventory volume.*

3. Paired T Test @ 95% (α=0.05) for all sample polygons
mean difference = 17.184 m^3/ha
p - value for mean difference = 0.239
**since p-value > α, the difference is not significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There were no significant differences within any of the GTGs.

5. Correlation @ 95% (α=0.05) for all samples
Correlation co-efficient r = 0.679
p value for correlation co-efficient < 0.001
∴ correlation is significant

MERRITT TSA Inventory Audit:
Audit Volume vs. Inventory Volume (by GTG)
(Tree Class 1 & 2, less decay only, 12.5cm + dbh)



Letter symbols correspond to map label GTG's as follows:

A	*pure F*	K	*S Pl , S Decid.*
B	*FC, FCy, FH, FS*	L	*pure Pl*
C	*FPl, FPy, FDecid., Py, Pa*	M	*Pl F, Pl S (and Pl B)*
H	*B, BH, BS*	N	*Pl Decid.*
J	*SF, SH (and SC), SB*		

Audit Volume (Kozak) vs. Ground Attribute Volume (Predicted in VDYP): *"VDYP model" bias (n=50)*

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 12.5 cm + net merch. less decay only /Tree class 1,2))*

207——————**246**——————**285** Audit Volume (15.8% sampling error)

200——————**231**——————**262** Ground Attribute Volume (predicted in VDYP) (13.3% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$$R = \frac{\text{average audit volume}}{\text{average ground attribute volume predicted in VDYP}} = 1.06$$

1.0
↓

0.97——————**1.06**——————**1.16**

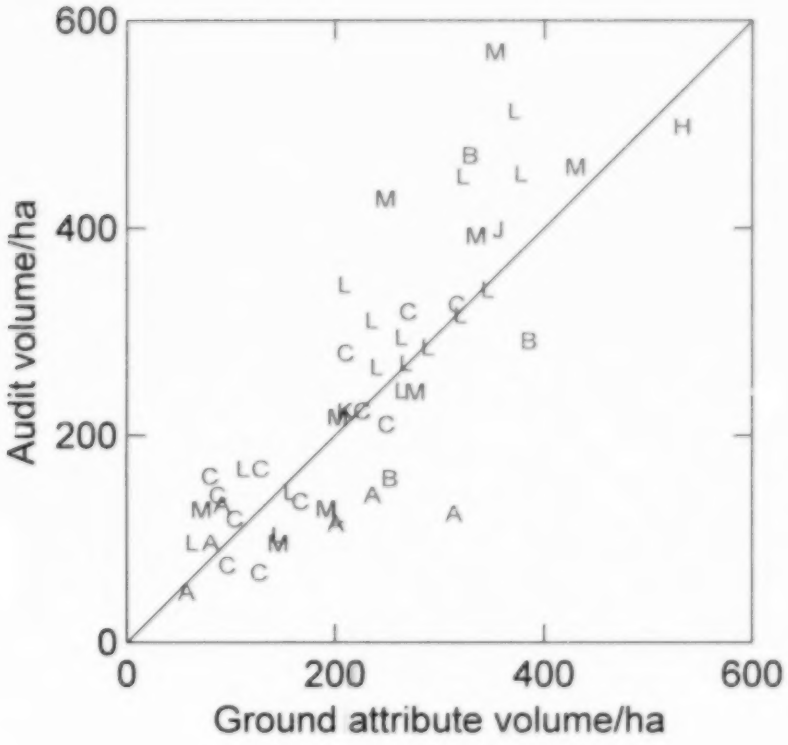
* *Since 1.0 is within the interval, the ratio indicates that there is no significant difference between the audit volume and the ground attribute volume.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons
mean difference = 14.928 m^3/ha
p - value for mean difference = 0.171
**since p - value > α, the difference is not significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There were no significant differences among any GTGs.

5. Correlation @95%($\alpha = 0.05$) for all samples
Correlation co-efficient r = 0.831
p - value for correlation co-efficient < 0.001
∴ correlation is significant

MERRITT TSA Inventory Audit:
Audit Volume (Kozak) vs. Ground Attribute Volume (Predicted in VDYP) by GTG
(Tree Class 1 & 2, less decay only, 12.5cm + dbh)



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H	*B, BH, BS*	N	*Pl Decid.*
J	*SF, SH (and SC), SB*		

Ground Attribute Volume (predicted in VDYP) vs. Inventory Volume (predicted in VDYP): *"Attribute" Bias (n=50)*

1. Average volumes/ha and confidence interval @ 95%

(Utilization level : 12.5 cm + net merch. less decay only, Tree Class 1,2)]

200——————**231**——————**262** Ground Attribute Volume (predicted in VDYP) (13.3% sampling error)

197——————**229**——————**260** Inventory Volume (map label attributes predicted in VDYP) (13.9% sampling error)

2. Ratio Analysis : Ratio of Means @ 95%

$$R = \frac{\text{average ground attribute volume (VDYP)}}{\text{average inventory volume (VDYP)}} = 1.01$$

1.0 ↓

0.90——————**1.01**——————**1.12**

* *The ratio indicates that there is no significant difference between the ground attribute volume predicted in the VDYP and the inventory volume predicted in the VDYP.*

3. Paired T Test @ 95% ($\alpha = 0.05$) for all sample polygons

mean difference = 2.256 m^3/ha

p - value for mean difference = 0.859

**since p - value > α, the difference is not significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG

There were no significant differences within any of the GTGs.

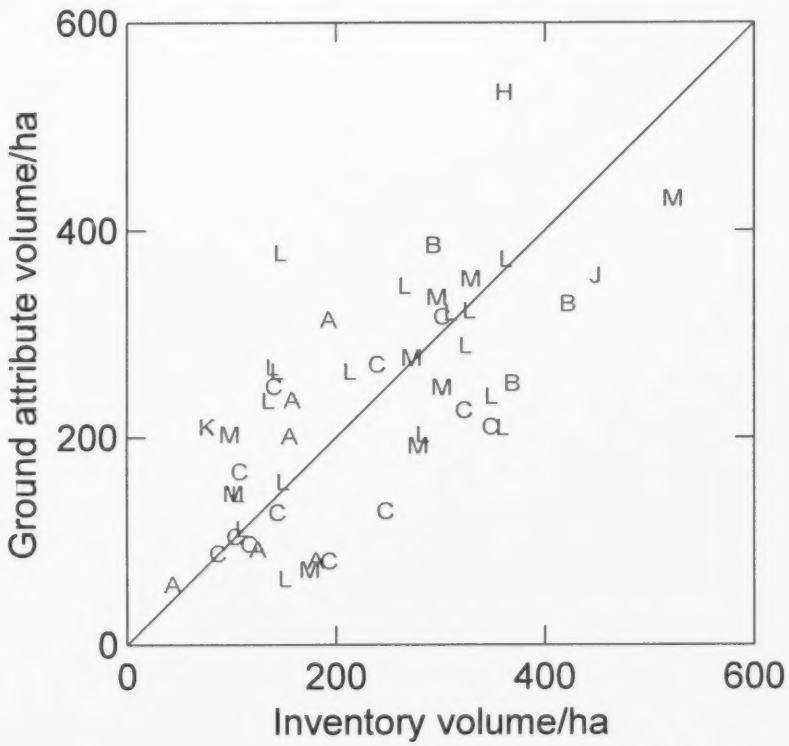
5. Correlation @95%($\alpha = 0.05$) for all samples

Correlation co-efficient r = 0.670

p - value for correlation co-efficient < 0.001

∴ correlation is significant

MERRITT TSA Inventory Audit:
Ground Attribute Volume (Predicted in VDYP) vs. Inventory Volume (Predicted in VDYP) by GTG
(Tree Class 1 & 2, less decay only, 12.5cm + dbh)



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J	*SF, SH (and SC), SB*		

Audit Volume (Kozak) vs. Inventory Volume (Predicted in VDYP) (compilation excluding audit plots that field crew judged "outside of polygon") (n=50)

1. Average Volumes/ha and Confidence Interval @ 95% *(Utilization level : 12.5 cm + net merch. less decay only/Tree Class 1,2)*

207——————**246**——————**285** Audit Volume (15.8% sampling error)

197——————**229**——————**260** Inventory Volume (map label attributes predicted in VDYP) (13.9% sampling error)

2. Ratio Analysis : Ratio of Means @95%

$$R = \frac{\text{average audit volume}}{\text{average inventory volume}} = 1.08$$

1.0
↓

0.95——————**1.08**——————**1.20**

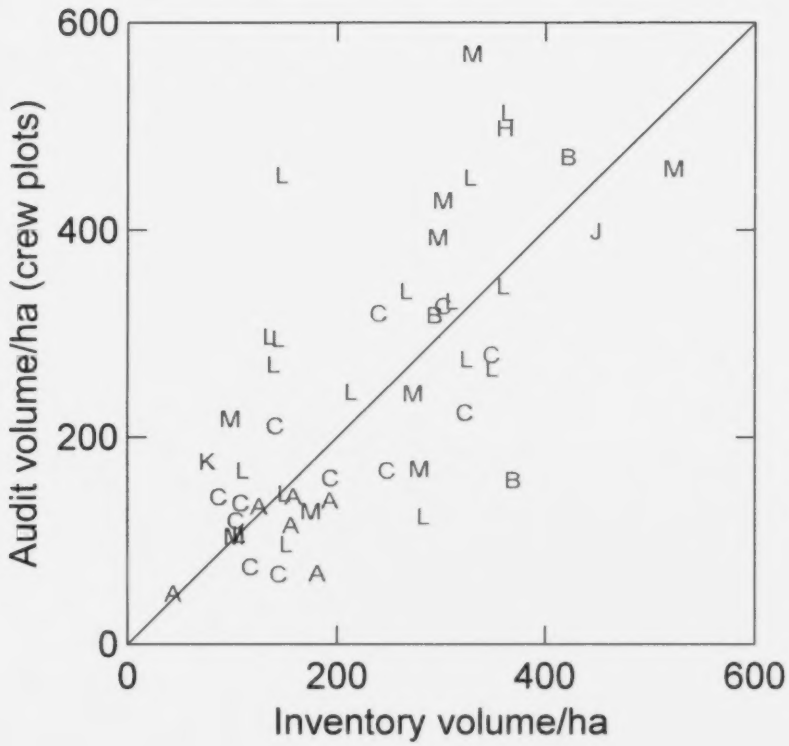
* *Since 1.0 is within the interval, the ratio indicates that there is no significant difference between the audit volume (based on the crew compilation) and the inventory volume.*

3. Paired T Test @ 95% (α=0.05) for all sample polygons
mean difference = 17.312 m^3/ha
p - value for mean difference = 0.226
**since p-value > α, the difference is not significant*

4. Paired T Test @ 95% for all sample polygons by map label GTG
There were no significant differences within any of the GTGs.

5. Correlation @ 95% (α=0.05) for all samples
Correlation co-efficient r = 0.694
p value for correlation co-efficient < 0.001
∴ correlation is significant

MERRITT TSA Inventory Audit:
Audit Volume vs. Inventory Volume (by GTG)
(compilation excluding audit plots that field crew judged "outside of polygon")
(Tree Class 1 & 2, less decay only, 12.5cm + dbh)



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J	*SF, SH (and SC), SB*		

Inventory Classification Assessment

- 62% of the growth type groups from the inventory (ie. map labels) matched the audit growth type groups.
- the growth type group distribution for the 50 inventory audit samples is as follows (the bold italic entries on the diagonal in the table indicate a GTG match between the audit and the inventory):

Audit GTG	***Inventory GTG (columns)***									
(rows)	A	B	C	H	J	K	L	M	N	*total*
A	***4***	0	4	0	0	0	0	0	0	8
B	1	***3***	3	0	0	0	0	1	0	8
C	1	0	***3***	0	0	0	0	0	0	4
H	0	0	0	***1***	0	0	0	0	0	1
J	0	0	0	0	***1***	0	0	1	0	2
K	0	0	0	0	0	***0***	0	1	0	1
L	0	0	0	0	0	0	***14***	1	0	15
M	0	0	2	0	0	1	2	***5***	0	10
N	0	0	0	0	0	0	1	0	***0***	1
total	6	3	12	1	1	1	17	9	0	**50**

Letter symbols correspond to GTG's as follows:

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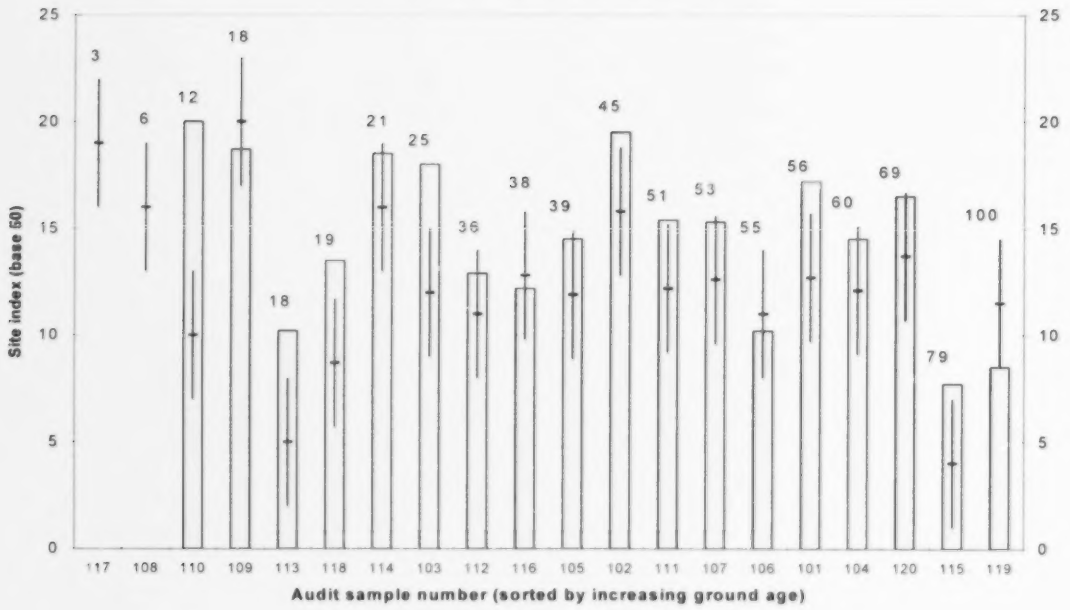
B	*FC, FCy, FH, FS*	L	*pure PI*
C	*FPI, FPy, FDecid., Py, Pa*	M	*PI F, PI S (and PI B)*
H	*B, BH, BS*	N	*PI Decid.*
J	*SF, SH (and SC), SB*		

Immature Site Index and Classification Assessment

- **55 %** of the growth type group assignments from the inventory (ie. map labels) matched the corresponding audit growth type group assignment.

MERRITT TSA Inventory Audit:
Comparison of Inventory and Audit Site Index
for Immature Samples



Notes:

- shaded bars correspond to ***audit site index*** values
- tick marks on vertical lines represent ***inventory site index*** (vertical lines have arbitrarily been set at ±3m around site index)
- numbers at the top of the bars corresponds to ground total age
- audit site indices based on BH age where available (using SiteTool)
- two samples were too young to assign audit site index (TH<2m)
- inventory site index was within 3m of the audit site index for 10 out of 18 samples (inventory site index was more than 3m lower than the audit site index for 8 samples)
- audit TH species did not match inventory leading species for 4 samples (#110, 112, 115, 117) (no alternate top height spp were measured).